

CLAIMS

What is claimed is:

- 1 / 1. An adaptive differential pulse code modulation system comprising:
- 2 an encoder including:
- 3 a subtractor configured for deriving a difference signal E_j , the difference
- 4 signal E_j being the difference between an input signal Y_j and a predicted
- 5 signal S_j , j representing a sample period;
- 6 a quantizer configured for quantizing the difference signal E_j to obtain a
- 7 numerical representation N_j for transmission to an encoder inverse quantizer
- 8 for deriving a regenerated difference signal D_j , and to a decoder inverse
- 9 quantizer coupled to the quantizer through a network for deriving the
- 10 regenerated difference signal D_j ,
- 11 an encoder adder configured for deriving a reconstructed input signal X_j ,
- 12 the reconstructed input signal X_j being the sum of the regenerated difference
- 13 signal D_j and the predicted signal S_j ;
- 14 an encoder whitening filter F_e configured for receiving the reconstructed
- 15 input signal X_j and for generating a filtered reconstructed signal X_j^f , the
- $$X_j^f = X_j - a_1^f X_{j-1} - a_2^f X_{j-2} - \dots a_n^f X_{j-n}$$
- 16 filtered reconstructed signal X_j^f being generated according to the equation:
- 17 X_{j-n} being a value of reconstructed input signal X_j at sample period $j-n$,
- 18 and;

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19 n being a number of filter tap coefficients a_n^f corresponding to the
20 whitening filter F_e ;
21 an encoder predictor P_{ep} configured for receiving the reconstructed input
22 signal X_j and for generating a predicted signal S_{jp} , the predicted signal S_{jp}
23 being at least constituent to predicted signal S_j and being generated according
24 to the equation:

$$25 \quad S_{jp} = a_1^j S_{j-1} + a_2^j S_{j-2} \dots a_{n_p}^j S_{j-n_p}$$

26 S_{j-n_p} being a value of the predicted signal S_j at sample period $j-n_p$, and
27 n_p being a number of predictor coefficients $a_{n_p}^j$ corresponding to the
28 predictor P_{ep} ; and
29 an encoder feedback loop configured for applying the predicted signal S_j
30 to the adder;
31 transmission means configured for transmitting the numerical
32 representation N_j from the encoder to a decoder; and
33 the decoder including:

34 the decoder inverse quantizer coupled to the quantizer through a network
35 and configured for receiving the numerical representation N_j and for deriving
36 the regenerated difference signal D_j therefrom,
37 a decoder adder configured for deriving the reconstructed input signal X_j ,
38 the reconstructed input signal X_j being the sum of the regenerated difference
39 signal D_j and the predicted signal S_j ;

40 a decoder whitening filter F_d configured for receiving the reconstructed
 41 input signal X_j and for generating the filtered reconstructed signal X_j^f , the
 42 filtered reconstructed signal X_j^f being generated according to the equation:

$$43 \quad X_j^f = X_j - a_{f1}^f X_{j-1} - a_{f2}^f X_{j-2} - \dots - a_{fn}^f X_{j-n}$$

44 X_{j-n} being a value of reconstructed signal X_j at sample period $j-n$, and
 45 n being the number of filter tap coefficients a_{fn}^f corresponding to the
 46 whitening filter F_d ;

47 a decoder predictor P_{dp} configured for receiving the reconstructed input
 48 signal X_j and for generating a predicted signal S_{jp} , the predicted signal S_{jp}
 49 being at least constituent to predicted signal S_j and being generated according
 50 to the equation:

$$51 \quad S_{jp} = a_{j1}^j S_{j-1} + a_{j2}^j S_{j-2} \dots + a_{jnp}^j S_{j-np}$$

52 S_{j-np} being a value of the predicted signal S_j at sample period $j-n_p$, and
 53 n_p being the number of predictor coefficients a_{jnp}^j corresponding to the
 54 predictor P_{dp} ; and

55 a decoder feedback loop configured for applying the predicted signal S_j to
 56 the decoder adder.

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1 2. The system of claim 1, further comprising:

2 a second encoder predictor P_{ez} configured for receiving the regenerated
 3 difference signal D_j and for generating a predicted signal S_{jz} ;

4 a second encoder adder configured for deriving the predicted signal S_j at
 5 the encoder, the predicted signal S_j being the sum of the predicted signal S_{jp} and
 6 the predicted signal S_{jz} ;

7 a second decoder predictor P_{dz} configured for receiving the regenerated
 8 difference signal D_j and for generating a predicted signal S_{jz} ; and

9 a second decoder adder configured for deriving the predicted signal S_j at
 10 the decoder, the predicted signal S_j being the sum of the predicted signal S_{jp} and
 11 the predicted signal S_{jz} .

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1 3. The system of claim 1 wherein:

2 n_p is 2;

3 the predictor coefficient a_1^j is updated according to the equation:

$$4 \quad a_1^{j+1} = a_1^j(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

5 δ_1 and g_1 being proper positive constants, and

6 F_1 being a nonlinear function; and

7 the predictor coefficient a_2^j is updated according to the equation:

$$8 \quad a_2^{j+1} = a_2^j(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^j);$$

9 δ_2 and g_2 being proper positive constants, and

10 F_2 being a nonlinear function.

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1 4. The system of claim 1 wherein:

2 n is 2;

3 the filter tap coefficient a_1^f is updated at each sample period j according to
4 the generalized equation:

$$5 \quad a_1^{f,j+1} = a_1^{f,j}(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

6 δ_1 and g_1 being proper positive constants, and

7 F_1 being a nonlinear function; and

8 the filter tap coefficients a_2^f is updated at each sample period j according to
9 the generalized equation:

$$10 \quad a_2^{f,j+1} = a_2^{f,j}(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^{f,j})$$

11 δ_2 and g_2 being proper positive constants, and

12 F_2 being a nonlinear function.

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1 5. The system of claim 4 wherein:

2 the filter tap coefficient $a_1^{f,j}$ is updated according to the equation:

$$3 \quad a_1^{f,j+1} = a_1^{f,j} \left(1 - \left(\frac{128}{32768} \right) \right) + 192 * \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f]; \text{ and}$$

4 the filter tap coefficient $a_2^{f,j}$ is updated according to the equation:

$$5 \quad a_2^{f,j+1} = a_2^{f,j} \left(1 - \left(\frac{256}{32768} \right) \right) - \left(\frac{1}{32} \right) a_1^{f,j} \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] + 128 * \text{sgn}[X_j^f] \text{sgn}[X_{j-2}^f];$$

6 $\text{sgn}[\]$ being a sign function that returns a value of 1 for a nonnegative

7 argument and a value of -1 for a negative argument.

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1 6. The system of claim 5 wherein at every other sample period j ,
 2 the filter tap coefficient a^{f+1}_2 is maintained in a range $-12288 \leq a^{f+1}_2 \leq$
 3 12288; and
 4 the filter tap coefficient a^{f+1}_1 is maintained in a range $-(15360 - a^{f+1}_2) \leq$
 5 $a^{f+1}_1 \leq (15360 - a^{f+1}_2)$;
 6 whereby a^{f+1}_1 is set equal to $(15360 - a^{f+1}_2)$ when $a^{f+1}_1 > 15360 - a^{f+1}_2$; and
 7 whereby a^{f+1}_1 is set equal to $-(15360 - a^{f+1}_2)$ when $a^{f+1}_1 < -(15360 - a^{f+1}_2)$.

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 1 7. The system of claim 5, further comprising:
 2 a second encoder predictor P_{ez} configured for receiving the regenerated
 3 difference signal D_j and for generating a predicted signal S_{jz} ;
 4 a second encoder adder configured for deriving the predicted signal S_j at
 5 the encoder, the predicted signal S_j being the sum of the predicted signal S_{jp} and
 6 the predicted signal S_{jz} ;
 7 a second decoder predictor P_{dz} configured for receiving the regenerated
 8 difference signal D_j and for generating a predicted signal S_{jz} ; and
 9 a second decoder adder configured for deriving the predicted signal S_j at
 10 the decoder, the predicted signal S_j being the sum of the predicted signal S_{jp} and
 11 the predicted signal S_{jz} .

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1 8. The system of claim 1 wherein at every other sample period j , the predictor
2 coefficient a_{np} corresponding to the predictors P_{ep} and P_{dp} is maintained
3 unchanged.

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1 9. The system of claim 8, such that if for even j :

2
$$a_1^{j+1} = a_1^j, \text{ and}$$

3
$$a_2^{j+1} = a_2^j,$$

4 then for odd j :

5
$$a_1^{j+1} = a_1^{j-1} \left(1 - \left(\frac{127.5}{32768} \right) \right) + 191.25 * \text{sgn}[X_{j-1}^f] \text{sgn}[X_{j-2}^f] + 192 * \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f], \text{ and}$$

6
$$a_2^{j+1} = a_2^{j-1} \left(1 - \left(\frac{510}{32768} \right) \right) - \left(\frac{1016}{32768} \right) \lim[a_1^{j-1}] \text{sgn}[X_{j-1}^f] \text{sgn}[X_{j-2}^f] + 127 * \text{sgn}[X_{j-1}^f] \text{sgn}[X_{j-3}^f]$$

$$- \left(\frac{1}{32} \right) \lim[a_1^{j-1}] \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] + 128 * \text{sgn}[X_j^f] \text{sgn}[X_{j-2}^f],$$

7 $\text{sgn}[\]$ being a sign function that returns a value of 1 for a nonnegative
8 argument and a value of -1 for a negative argument, and

9
$$\lim[a_1^{j-1}] = a_1^{j-1} \text{ for } -8192 \leq a_1^{j-1} \leq 8191,$$

10
$$\lim[a_1^{j-1}] = -8192 \text{ for } a_1^{j-1} < -8191, \text{ and}$$

11
$$\lim[a_1^{j-1}] = 8192 \text{ for } a_1^{j-1} > 8191.$$

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- 1 10. An encoder for encoding digital audio signals, comprising:
 - 2 a subtractor configured for deriving a difference signal E_j , the difference
 - 3 signal E_j being the difference between an input signal Y_j and a predicted
 - 4 signal S_j , j representing a sample period;
 - 5 a quantizer configured for quantizing the difference signal E_j to obtain a
 - 6 numerical representation N_j for transmission to an encoder inverse quantizer
 - 7 for deriving a regenerated difference signal D_j , and to a decoder inverse
 - 8 quantizer coupled to the quantizer for deriving the regenerated difference
 - 9 signal D_j ;
 - 10 an adder configured for deriving a reconstructed input signal X_j , the
 - 11 reconstructed input signal X_j being the sum of the regenerated difference
 - 12 signal D_j and the predicted signal S_j ;
 - 13 a whitening filter configured for receiving the reconstructed input signal
 - 14 X_j and for generating a filtered reconstructed signal X_j^f , the filtered
 - 15 reconstructed signal X_j^f being generated according to the equation:
$$X_j^f = X_j - a_1^f X_{j-1} - a_2^f X_{j-2} - \dots - a_n^f X_{j-n}^f$$
 - 16 X_{j-n}^f being a value of filtered reconstructed signal X_j^f at sample period $j-n$,
 - 17 and
 - 18 n being a number of filter tap coefficients a_n^f corresponding to the
 - 19 whitening filter;
 - 20 a predictor configured for receiving the reconstructed input signal X_j and
 - 21 for generating a predicted signal S_{jp} , the predicted signal S_{jp} being at least

23 constituent to predicted signal S_j and being generated according to the
24 equation:

25
$$S_{jp} = a_1 S_{j-1} - a_2 S_{j-2} - \dots a_{n_p} S_{j-n_p}$$

26 S_{j-n_p} being a value of the predicted signal S_j at sample period $j-n_p$, and
27 n_p being a number of predictor coefficients a_{n_p} corresponding to the
28 predictor; and
29 a feedback loop configured for applying the predicted signal S_j to the
30 adder.

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1 11. The system of claim 10, the encoder further comprising:

2 a second predictor configured for receiving the regenerated difference
3 signal D_j and for generating a predicted signal S_{jz} , the predicted signal S_{jz} being
4 at least constituent to predicted signal S_j ; and

5 a second adder configured for deriving the predicted signal S_j , the
6 predicted signal S_j being the sum of the predicted signal S_{jp} and the predicted
7 signal S_{jz} .

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1 12. The system of claim 10 wherein:

2 n is 2;

3 the filter tap coefficient a_1^f is updated at each sample period j according to
4 the generalized equation:

$$a_1^{fj+1} = a_1^{fj}(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

δ_1 and g_1 being proper positive constants, and

F_1 being a nonlinear function;

the filter tap coefficients a_2^f is updated at each sample period j according to the generalized equation:

$$a_2^{fj+1} = a_2^{fj}(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^{fj})$$

δ_2 and g_2 being proper positive constants, and

F_2 being a nonlinear function.

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1 13. The system of claim 12 wherein:

2 the filter tap coefficient a_1^f is updated according to the equation:

$$a_1^{fj+1} = a_1^{fj} \left(1 - \left(\frac{128}{32768} \right) \right) + 192 * \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] \text{ and}$$

4 the filter tap coefficient a_2^f is updated according to the equation:

$$a_2^{fj+1} = a_2^{fj} \left(1 - \left(\frac{256}{32768} \right) \right) - \left(\frac{1}{32} \right) a_1^{fj} \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] + 128 * \text{sgn}[X_j^f] \text{sgn}[X_{j-2}^f],$$

6 $\text{sgn}[]$ being a sign function that returns a value of 1 for a nonnegative
7 argument and a value of -1 for a negative argument.

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1 14. The system of claim 13 wherein at every other sample period j ,

2 the filter tap coefficient a_1^{fj+1} is maintained in a range $-12288 \leq a_1^{fj+1} \leq$

3 12288; and

4 the filter tap coefficient a^{f+1}_1 is maintained in a range $-(15360 - a^{f+1}_2) \leq$

5 $a^{f+1}_1 \leq (15360 - a^{f+1}_2)$;

6 whereby a^{f+1}_1 is set equal to $(15360 - a^{f+1}_2)$ when $a^{f+1}_1 > 15360 - a^{f+1}_2$; and

7 whereby a^{f+1}_1 is set equal to $-(15360 - a^{f+1}_2)$ when $a^{f+1}_1 < -(15360 - a^{f+1}_2)$.

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1 15. The system of claim 10 wherein at every other sample period j , the predictor

2 coefficient a_{np} corresponding to the predictor is maintained unchanged.

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1 16. The system of claim 10, wherein the encoder is constituent to or coupled to a

2 videoconferencing device or application.

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- 1 17. A decoder for decoding digital audio signals encoded by a properly
 2 associated encoder, comprising:
- 3 an inverse quantizer coupled to the encoder and configured for receiving
 4 a numerical representation N_j and for deriving a regenerated difference signal
 5 D_j therefrom, the numerical representation N_j being a quantized
 6 representation of a difference signal E_j , the difference signal E_j being the
 7 difference between an input signal Y_j and a predicted signal S_j , j representing
 8 a sample period;
- 9 an adder configured for deriving a reconstructed input signal X_j , the
 10 reconstructed input signal X_j being the sum of the regenerated difference
 11 signal D_j and the predicted signal S_j ;
- 12 a whitening filter configured for receiving the reconstructed input signal
 13 X_j and for generating a filtered reconstructed signal X_j^f , the filtered
 14 reconstructed signal X_j^f being generated according to the equation:
- 15
$$X_j^f = X_j - a_1^f X_{j-1} - a_2^f X_{j-2} - \dots - a_n^f X_{j-n}^f$$
- 16 X_{j-n}^f being a value of filtered reconstructed signal X_j^f at sample period $j-n$,
 17 and
 18 n being a number of filter tap coefficients a_n^f corresponding to the
 19 whitening filter;
- 20 a predictor configured for receiving the reconstructed input signal X_j and
 21 for generating a predicted signal S_{jp} , the predicted signal S_{jp} being at least

22 constituent to predicted signal S_j and being generated according to the
 23 equation:

$$24 \quad S_{jp} = a_1 S_{j-1} - a_2 S_{j-2} - \dots - a_{n_p} S_{j-n_p}$$

25 S_{j-n_p} being a value of the predicted signal S_j at sample period $j-n_p$, and
 26 n_p being a number of predictor coefficients a_{n_p} corresponding to the
 27 predictor; and
 28 a feedback loop configured for applying the predicted signal S_j to the
 29 adder.

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1 18. The system of claim 17, the decoder further comprising:

2 a second predictor configured for receiving the regenerated difference
 3 signal D_j and for generating a predicted signal S_{jz} , the predicted signal S_{jz} being
 4 at least constituent to predicted signal S_j ; and

5 a second adder configured for deriving the predicted signal S_j , the
 6 predicted signal S_j being the sum of the predicted signal S_{jp} and the predicted
 7 signal S_{jz} .

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1 19. The system of claim 17 wherein:

2 n is 2;

3 the filter tap coefficient a_1^f is updated at each sample period j according to
 4 the generalized equation:

$$a_1^{fj+1} = a_1^{fj}(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

δ_1 and g_1 being proper positive constants, and

F_1 being a nonlinear function;

the filter tap coefficients a_2^f is updated at each sample period j according to the generalized equation:

$$a_2^{fj+1} = a_2^{fj}(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^{fj})$$

δ_2 and g_2 being proper positive constants, and;

F_2 being a nonlinear function.

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1 20. The system of claim 19 wherein:

2 the filter tap coefficient a_1^f is updated according to the equation:

$$a_1^{fj+1} = a_1^{fj} \left(1 - \left(\frac{128}{32768} \right) \right) + 192 * \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] \text{ and}$$

4 the filter tap coefficient a_2^f is updated according to the equation:

$$a_2^{fj+1} = a_2^{fj} \left(1 - \left(\frac{256}{32768} \right) \right) - \left(\frac{1}{32} \right) a_1^{fj} \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] + 128 * \text{sgn}[X_j^f] \text{sgn}[X_{j-2}^f]$$

6 $\text{sgn}[]$ being a sign function that returns a value of 1 for a nonnegative
7 argument and a value of -1 for a negative argument.

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1 21. The system of claim 20 wherein at every other sample period j ,

2 the filter tap coefficient a_1^{fj+1} is maintained in a range $-12288 \leq a_1^{fj+1} \leq$

3 12288; and

4 the filter tap coefficient a^{f+1}_1 is maintained in a range $-(15360 - a^{f+1}_2) \leq$

5 $a^{f+1}_1 \leq (15360 - a^{f+1}_2)$;

6 whereby a^{f+1}_1 is set equal to $(15360 - a^{f+1}_2)$ when $a^{f+1}_1 > 15360 - a^{f+1}_2$; and

7 whereby a^{f+1}_1 is set equal to $-(15360 - a^{f+1}_2)$ when $a^{f+1}_1 < -(15360 - a^{f+1}_2)$.

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1 22. The system of claim 17 wherein at every other sample period j , the predictor

2 coefficient a_{np} corresponding to the predictor is maintained unchanged.

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1 23. The system of claim 17, wherein the decoder is constituent to or coupled to a

2 videoconferencing device or application.

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- 1 ~~24~~. A method for encoding and decoding digital audio signals, comprising the
 2 steps of:
- 3 deriving a difference signal E_j at an encoder, the difference signal E_j being
 4 the difference between an input signal Y_j and a predicted signal S_j , j
 5 representing a sample period;
- 6 quantizing the difference signal E_j to obtain a numerical representation N_j
 7 for transmitting to an encoder inverse quantizer for deriving a regenerated
 8 difference signal D_j , and to a decoder inverse quantizer coupled to the
 9 quantizer through a network for deriving the regenerated difference signal
 10 D_j ;
- 11 deriving a reconstructed input signal X_j at a first adder, the reconstructed
 12 input signal X_j being the sum of the regenerated difference signal D_j and the
 13 predicted signal S_j ;
- 14 receiving the reconstructed input signal X_j at a whitening filter F_e ;
- 15 generating a filtered reconstructed signal X_j^f by the whitening filter F_e , the
 16 filtered reconstructed signal X_j^f being generated according to the equation:
- 17
$$X_j^f = X_j - a^f_1 X_{j-1} - a^f_2 X_{j-2} - \dots - a^f_n X_{j-n}$$
- 18 X_{j-n}^f being a value of filtered reconstructed signal X_j^f at sample period $j-n$,
 19 and
 20 n being a number of filter tap coefficients a^f_n corresponding to the
 21 whitening filter F_e ;
- 22 receiving the reconstructed input signal X_j at a predictor P_{ep} ;

23 generating a predicted signal S_{jp} by the predictor P_{ep} , the predicted signal
 24 S_{jp} being at least constituent to predicted signal S_j and being generated
 25 according to the equation:

$$26 \quad S_{jp} = a_{11} S_{j-1} - a_{12} S_{j-2} - \dots - a_{1n_p} S_{j-n_p}$$

27 S_{j-n_p} being a value of the predicted signal S_j at sample period $j-n_p$, and
 28 n_p being a number of predictor coefficients a_{1n_p} corresponding to the
 29 predictor P_{ep} ;

30 applying the predicted signal S_j to the first adder to provide feedback;
 31 receiving the numerical representation N_j at a decoder;
 32 deriving the regenerated difference signal D_j from the numerical
 33 representation N_j ,

34 deriving the reconstructed input signal X_j at a second adder, the
 35 reconstructed input signal X_j being the sum of the regenerated difference
 36 signal D_j and the predicted signal S_j ;

37 receiving the reconstructed input signal X_j at a whitening filter F_d ;

38 generating a filtered reconstructed signal X_j^f by the whitening filter F_d , the
 39 filtered reconstructed signal X_j^f being generated according to the equation:

$$40 \quad X_j^f = X_j - a_{f1} X_{j-1} - a_{f2} X_{j-2} - \dots - a_{fn} X_{j-n}$$

41 X_{j-n}^f being a value of filtered reconstructed signal X_j^f at sample period $j-n$;
 42 n being a number of filter tap coefficients a_{fn} corresponding to the
 43 whitening filter F_d ;

44 receiving the reconstructed input signal X_j at a predictor P_{dp} ;

45 generating a predicted signal S_{jp} by the predictor P_{dp} , the predicted signal
46 S_{jp} being at least constituent to predicted signal S_j and being generated
47 according to the equation:

$$48 \quad S_{jp} = a_{11} S_{j-1} - a_{12} S_{j-2} - \dots - a_{1n_p} S_{j-n_p}$$

49 S_{j-n_p} being a value of the predicted signal S_j at sample period $j-n_p$, and
50 n_p being a number of predictor coefficients a_{1n_p} corresponding to the
51 predictor P_{dp} ; and
52 applying the predicted signal S_j to the second adder to provide feedback.

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1 25. The method of claim 24, further comprising the steps of:

2 receiving the regenerated difference signal D_j at a predictor P_{ez} at the
3 encoder;

4 generating a predicted signal S_{jz} by the predictor P_{ez} ;

5 deriving the predicted signal S_j at the encoder, the predicted signal S_j
6 being the sum of the predicted signal S_{jp} and the predicted signal S_{jz} ;

7 receiving the regenerated difference signal D_j at a predictor P_{dz} at the
8 decoder;

9 generating the predicted signal S_{jz} by the predictor P_{dz} ; and

10 deriving the predicted signal S_j at the decoder, the predicted signal S_j
11 being the sum of the predicted signal S_{jp} and the predicted signal S_{jz} .

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1 26. The method of claim 24 wherein n_p is 2, further comprising the steps of:

2 updating the predictor coefficient a_1^j according to the equation:

$$3 \quad a_1^{j+1} = a_1^j(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

4 δ_1 and g_1 being proper positive constants, and

5 F_1 being a nonlinear function; and

6 updating the predictor coefficient a_2^j according to the equation:

$$7 \quad a_2^{j+1} = a_2^j(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^j)$$

8 δ_2 and g_2 being proper positive constants, and;

9 F_2 being a nonlinear function.

1 27. The method of claim 24 wherein n is 2, further comprising the steps of:

2 updating the filter tap coefficient a_1^f at each sample period j according to
3 the generalized equation:

$$4 \quad a_1^{fj+1} = a_1^{fj}(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

5 δ_1 and g_1 being proper positive constants, and

6 F_1 being a nonlinear function; and

7 updating the filter tap coefficients a_2^f at each sample period j according to
8 the generalized equation:

$$9 \quad a_2^{fj+1} = a_2^{fj}(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^{fj})$$

10 δ_2 and g_2 being proper positive constants, and

11 F_2 being a nonlinear function.

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1 28. The method of claim 27 wherein:

2 the filter tap coefficient a_1^f is updated according to the equation:

3
$$a_1^{f,j+1} = a_1^{f,j} \left(1 - \left(\frac{128}{32768} \right) \right) + 192 * \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f], \text{ and}$$

4 the filter tap coefficient a_2^f is updated according to the equation:

5
$$a_2^{f,j+1} = a_2^{f,j} \left(1 - \left(\frac{256}{32768} \right) \right) - \left(\frac{1}{32} \right) a_1^{f,j} \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] + 128 * \text{sgn}[X_j^f] \text{sgn}[X_{j-2}^f]$$

6 $\text{sgn}[\]$ being a sign function that returns a value of 1 for a nonnegative

7 argument and a value of -1 for a negative argument.

1 29. The method of claim 28 wherein at every other sample period j ,

2 the filter tap coefficient a^{f+1}_2 is maintained in a range $-12288 \leq a^{f+1}_2 \leq$

3 12288; and

4 the filter tap coefficient a^{f+1}_1 is maintained in a range $-(15360 - a^{f+1}_2) \leq$

5 $a^{f+1}_1 \leq (15360 - a^{f+1}_2)$;

6 whereby a^{f+1}_1 is set equal to $(15360 - a^{f+1}_2)$ when $a^{f+1}_1 > 15360 - a^{f+1}_2$; and

7 whereby a^{f+1}_1 is set equal to $-(15360 - a^{f+1}_2)$ when $a^{f+1}_1 < -(15360 - a^{f+1}_2)$.

1 30. The method of claim 28, further comprising the steps of:

2 receiving the regenerated difference signal D_j at a predictor P_{ez} at the

3 encoder;

4 generating a predicted signal S_{jz} by the predictor P_{dz} ;

5 deriving the predicted signal S_j at the encoder, the predicted signal S_j
6 being the sum of the predicted signal S_{jp} and the predicted signal S_{jz} ;
7 receiving the regenerated difference signal D_j at a predictor P_{dz} at the
8 decoder;
9 generating the predicted signal S_{jz} by the predictor P_{dz} ; and
10 deriving the predicted signal S_j at the decoder, the predicted signal S_j
11 being the sum of the predicted signal S_{jp} and the predicted signal S_{jz} .

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1 31. The method of claim 28 wherein n_p is 2, further comprising the steps of:

2 updating the predictor coefficient a_1^j according to the equation:

$$3 \quad a_1^{j+1} = a_1^j(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

4 δ_1 and g_1 being proper positive constants, and

5 F_1 being a nonlinear function; and

6 updating the predictor coefficient a_2^j according to the equation:

$$7 \quad a_2^{j+1} = a_2^j(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^j)$$

8 δ_2 and g_2 being proper positive constants, and;

9 F_2 being a nonlinear function.

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1 32. A method for adapting coefficients in a two pole predictor in an adaptive
2 differential pulse code modulation system, comprising the steps of:

3 generating a filtered reconstructed signal X_j^f by a whitening filter F_e , the
4 filtered reconstructed signal X_j^f being generated according to the equation:

$$5 \quad X_j^f = X_j - a_1^f X_{j-1} - a_2^f X_{j-2} - \dots - a_n^f X_{j-n}^f$$

6 X_{j-n}^f being a value of filtered reconstructed signal X_j^f at sample period $j-n$,

7 and

8 n being a number of filter tap coefficients a_n^f corresponding to the

9 whitening filter F_e ;

10 updating a predictor coefficient a_1^j according to the equation:

$$11 \quad a_1^{j+1} = a_1^j (1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

12 δ_1 and g_1 being proper positive constants, and

13 F_1 being a nonlinear function; and

14 updating a predictor coefficient a_2^j according to the equation:

$$15 \quad a_2^{j+1} = a_2^j (1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^j)$$

16 δ_2 and g_2 being proper positive constants, and

17 F_2 being a nonlinear function.

1

1 33. The method of claim 32, further comprising the steps of:

2 updating the filter tap coefficient a_1^f at each sample period j according to

3 the generalized equation:

$$a_1^{fj+1} = a_1^{fj}(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

δ_1 and g_1 being proper positive constants, and

F_1 being a nonlinear function; and

updating the filter tap coefficients a_2^f at each sample period j according to the generalized equation:

$$a_2^{fj+1} = a_2^{fj}(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^{fj})$$

δ_2 and g_2 being proper positive constants, and

F_2 being a nonlinear function.

1

1 34. The method of claim 32 wherein:

2 the filter tap coefficient a_1^f is updated according to the equation:

$$a_1^{fj+1} = a_1^{fj} \left(1 - \left(\frac{128}{32768} \right) \right) + 192 * \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] \text{ and}$$

4 the filter tap coefficient a_2^f is updated according to the equation:

$$a_2^{fj+1} = a_2^{fj} \left(1 - \left(\frac{256}{32768} \right) \right) - \left(\frac{1}{32} \right) a_1^{fj} \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] + 128 * \text{sgn}[X_j^f] \text{sgn}[X_{j-2}^f]$$

6 $\text{sgn}[\]$ being a sign function that returns a value of 1 for a nonnegative
7 argument and a value of -1 for a negative argument.

1

1 35. The method of claim 34 wherein at every other sample period j ,

2 the filter tap coefficient a^{fj+1}_2 is maintained in a range $-12288 \leq a^{fj+1}_2 \leq$

3 12288; and

4 the filter tap coefficient a^{f+1}_1 is maintained in a range $-(15360 - a^{f+1}_2) \leq$

5 $a^{f+1}_1 \leq (15360 - a^{f+1}_2)$;

6 whereby a^{f+1}_1 is set equal to $(15360 - a^{f+1}_2)$ when $a^{f+1}_1 > 15360 - a^{f+1}_2$; and

7 whereby a^{f+1}_1 is set equal to $-(15360 - a^{f+1}_2)$ when $a^{f+1}_1 < -(15360 - a^{f+1}_2)$.

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1 36. A machine readable medium embodying instructions executable by a
2 machine to perform a method for adapting coefficients in a two pole predictor in
3 an adaptive differential pulse code modulation system, the method steps
4 comprising:

5 generating a filtered reconstructed signal X_j^f by a whitening filter, the
6 filtered reconstructed signal X_j^f being generated according to the equation:

$$7 \quad X_j^f = X_j - a_1^f X_{j-1} - a_2^f X_{j-2} - \dots - a_n^f X_{j-n}^f$$

8 X_{j-n}^f being a value of filtered reconstructed signal X_j^f at sample period $j-n$,

9 and

10 n being a number of filter tap coefficients a_n^f corresponding to the
11 whitening filter;

12 updating a predictor coefficient a_1^j according to the equation:

$$13 \quad a_1^{j+1} = a_1^j (1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

14 δ_1 and g_1 being proper positive constants, and

15 F_1 being a nonlinear function; and

16 updating a predictor coefficient a_2^j according to the equation:

$$17 \quad a_2^{j+1} = a_2^j (1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^j)$$

18 δ_2 and g_2 being proper positive constants, and

19 F_2 being a nonlinear function.

1

1

1 37. A digital circuit embodying instructions to perform a method for adapting
 2 coefficients in a two pole predictor in an adaptive differential pulse code
 3 modulation system, the method steps comprising:

4 generating a filtered reconstructed signal X_j^f by a whitening filter, the
 5 filtered reconstructed signal X_j^f being generated according to the equation:

$$6 \quad X_j^f = X_j - a_1^f X_{j-1} - a_2^f X_{j-2} - \dots - a_n^f X_{j-n}^f$$

7 X_{j-n}^f being a value of filtered reconstructed signal X_j^f at sample period $j-n$,

8 and

9 n being a number of filter tap coefficients a_n^f corresponding to the
 10 whitening filter;

11 updating a predictor coefficient a_1^j according to the equation:

$$12 \quad a_1^{j+1} = a_1^j (1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

13 δ_1 and g_1 being proper positive constants, and

14 F_1 being a nonlinear function; and

15 updating a predictor coefficient a_2^j according to the equation:

$$16 \quad a_2^{j+1} = a_2^j (1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^j)$$

17 δ_2 and g_2 being proper positive constants, and

18 F_2 being a nonlinear function.

1

1

- 1 38. An adaptive differential pulse code modulation system comprising:
- 2 at a first instance:
- 3 means for deriving a difference signal E_j , the difference signal E_j being the
- 4 difference between an input signal Y_j and a predicted signal S_j , j representing a
- 5 sample period;
- 6 means for quantizing the difference signal E_j to obtain a numerical
- 7 representation N_j ;
- 8 means for deriving a regenerated difference signal D_j based on the
- 9 numerical representation N_j ,
- 10 means for transmitting the numerical representation N_j to an inverse
- 11 quantizing means coupled to the quantizing means through a network;
- 12 means for deriving a reconstructed input signal X_j , the reconstructed input
- 13 signal X_j being the sum of the regenerated difference signal D_j and the
- 14 predicted signal S_j ;
- 15 means for generating a filtered reconstructed signal X_j^f , the filtered
- 16 reconstructed signal X_j^f being generated according to the equation:
- 17
$$X_j^f = X_j - a_1^f X_{j-1} - a_2^f X_{j-2} - \dots - a_n^f X_{j-n}^f$$
- 18 X_{j-n}^f being a value of filtered reconstructed signal X_j^f at sample period $j-n$,
- 19 and
- 20 n being a number of coefficients a_n^f corresponding to the means for
- 21 generating a filtered reconstructed signal;

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means for generating a predicted signal S_{jp} , the predicted signal S_{jp} being at least constituent to predicted signal S_j and being generated according to the equation:

$$S_{jp} = a_{j1} S_{j-1} - a_{j2} S_{j-2} - \dots a_{jnp} S_{j-np}$$

S_{j-np} being a value of the predicted signal S_j at sample period $j-n_p$, and n_p being a number of predictor coefficients a_{jnp} corresponding to the means for generating a predicted signal; and

feedback means for applying the predicted signal S_j to the means for deriving a reconstructed input signal X_j ;

at a second instance:

the inverse quantizing means for deriving the regenerated difference signal D_j from the numerical representation N_j ;

second means for deriving a reconstructed input signal X_j , the reconstructed input signal X_j being the sum of the regenerated difference signal D_j and the predicted signal S_j ;

second means for generating a filtered reconstructed signal X_j^f , the filtered reconstructed signal X_j^f being generated according to the equation:

$$X_j^f = X_j - a_{j1}^f X_{j-1}^f - a_{j2}^f X_{j-2}^f - \dots a_{jn}^f X_{j-n}^f$$

X_{j-n}^f being a value of filtered reconstructed signal X_j^f at sample period $j-n$, and

n being a number of coefficients a_n^f corresponding to the second means for generating a filtered reconstructed signal;

44 second means for generating a predicted signal S_{jp} , the predicted signal S_{jp}
45 being at least constituent to predicted signal S_j and being generated according
46 to the equation:

47
$$S_{jp} = a_1 S_{j-1} - a_2 S_{j-2} - \dots a_{n_p} S_{j-n_p}$$

48 S_{j-n_p} being a value of the predicted signal S_j at sample period $j-n_p$, and
49 n_p being a number of coefficients a_{n_p} corresponding to the means for
50 generating a predicted signal; and
51 feedback means for applying the predicted signal S_j to the means for
52 deriving a reconstructed input signal X_j .